The NASA Program Management Tool: A New Vision in Business Intelligence

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Abstract[1]— This paper describes a novel approach to business intelligence and program management for large technology enterprises like the U.S. National Aeronautics and Space Administration (NASA). Two key distinctions of the approach are that 1) standard business documents are the user interface, and 2) a "schema-less" XML database enables flexible integration of technology information for use by both humans and machines in a highly dynamic environment. The implementation utilizes patent-pending NASA software called the NASA Program Management Tool (PMT) and its underlying "schema-less" XML database called Netmark. Initial benefits of PMT include elimination of discrepancies between business documents that use the same information and "paperwork reduction" for program and project management in the form of reducing the effort required to understand standard reporting requirements and to comply with those reporting requirements. We project that the underlying approach to business intelligence will enable significant benefits in the timeliness, integrity and depth of business information available to decision makers on all organizational levels.

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1. INTRODUCTION

The Program Management Tool is a custom-built business intelligence solution for NASA to successfully manage large programs. It enables program and task managers to communicate success critical information on the status and progress of all program levels in an efficient and always current manner. PMT keeps track of project goals, risks, milestones and deliverables, and assists the proper allocation of financial, material, and human resources. It is well integrated with other agency-wide information systems.

PMT is like the nervous system of a complex organization like NASA —it rapidly transports vital information from its operating parts to decision-making authorities and back, allowing a program to move ahead in a coherent and efficient manner and to master changes in the environment fast and proactively.

PMT supports all essential program management activities and corresponding documents like: creation and monitoring of annual task plans; monthly reporting of technical, schedule, management, and budget status; tracking budget phasing plans; analyzing program risks and mitigation strategies; reporting and evaluating project life cycle costs; accessing convenient aggregated views; automatically creating Earned Value Management assessments, Quad-Charts and other reports.

PMT is more of an integrator than a standalone thus connecting multiple distributed resources across the agency; namely ERASMUS reporting system and to the NASA Technology Inventory Database (NTI), and the Integrated Financial Management System (IFMP) thereby significantly reducing cost and time for entering the same data multiple times into different systems.

The PMT data architecture is designed to support model-based program management by abstracting NASA 7120.5 project planning guidelines into the PMT either directly via data elements and management monitoring algorithms, and/or via middleware links to portfolio, risk, configuration, and other tools.

Management of large technology programs involves a significant amount of information, which is often delivered using standard templates that meet monthly, quarterly and

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yearly reporting requirements. Managers who need to be able to gather and understand large amounts of business information in busy meetings have a vital interest in the standardization of report formats. Therefore, information is not only required based on templates, but also required in the format of specific software packages such as Microsoft® Excel, Microsoft® Word, Microsoft® Powerpoint® and Adobe® Acrobat®. While the source of this information is often found in multiple databases with multiple schemas, and the destination of this information often goes to multiple databases with multiple schemas, the human readable format is most critical since management decisions are typically based on conversations and exchanges between humans not machines. Standard formats are required for exchanges between technical experts and decision-making authorities in order for the decision-making authorities to make informed choices using comparable information across the portfolio of selected projects.

Integrated business intelligence is an approach that not only enables automated exchange of information between machines, but also enables automated use of standard business documents, spreadsheets and presentations that are an integral part of the exchange of information between humans for decision making. Business documents become the user interface, and information entered once in business documents gets automatically aggregated and repurposed into standard outputs for use by both humans and machines. This approach is enabled by patent-pending software developed at the U.S. National Aeronautics & Space Administration (NASA), including a novel document-based program management application and its novel underlying "schema-less" XML database.

Key distinctions of the approach are:

(1) Standardized business documents are a key user interface (spreadsheets, presentations, documents), eliminating the need for information administration by automating the communication of information using standard templates, and

(2) A 'schema-less' XML database enables integration, eliminating the need for database administration by having a universal schema.

A key breakthrough of this approach is that the use of business documents as the inputs and outputs of the management system enables transparency up and down the management chain. Project managers can see how their project information gets summarized in the diversity of presentations and documents used by program managers. Program managers can also see the more detailed project information beyond the project summaries they normally receive. This approach eliminates discrepancies between multiple documents that use the same project information, since the multiple project documents are automatically created from the XML database.

2. Design Requirements

For the management of large technology programs the integration of heterogeneous and distributed technology information is required, and is feasible with modern information technologies. Heterogeneous information involves diverse data structures in structured databases, and unstructured information stored in spreadsheets, word processing documents, presentations and other formats used for human analysis and communication. In the end, it is humans who make management decisions, so this is not just an integration challenge, but also a challenge of composing information from heterogeneous sources for use in human communication and decision-making.

A key to addressing the data heterogeneity issue is the adoption and enforcement of standards across information systems. While XML is clearly emerging to be the lingua franca for databases and internet systems, it is encouraging to see the enforcement of standards even at the level of Microsoft® Word and Microsoft® Powerpoint® documents. For instance in the NASA enterprise the new ESR&T[2] program has explicitly specified the requirements and formats for monthly project reports. Each project is required to submit a monthly progress report, in accordance with its approved project plan or contract Statement of Work, that provides information on the progress of the project during the previous month, in the areas of technical accomplishments, status against schedule, spending, performance against Earned Value Management metrics, planned activities for the following month, and other information pertinent to the tracking and management of the project. The formats have been specified for Word and Powerpoint documents which will be the reporting formats for this program.

The key capabilities that thus must be incorporated in an effective program management information system for an enterprise such as NASA are summarized as follows:

(3) *Integrating information* from heterogeneous technology databases in a consistent manner, for example project, program and enterprise-level technology databases; past, current, and future technology databases; technical, managerial and financial databases.

(4) *Composing analyses and reports* from heterogeneous technology databases in support of diverse technology management processes, such as gap analyses, technology assessments, and technology roadmaps; and, historical problem/failure trend reports, bug/requirements tracking, concept/feature tracking.

(5) *Communicating technology information* among diverse technology development stakeholders and technology database systems in order to assess data pedigree and

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[2] Exploration systems research and technology

support effective decision making for diverse organizational processes, such as project and program management, internal and external reviews, intellectual property and investment management, gap analyses and technology forecasting; and diverse database systems.

3. PMT Features

PMT has been developed to meet the above mentioned requirements and the vision of a business intelligence solution that enables humans to communicate efficiently across organizational boundaries by seamlessly integrating heterogeneous data sources. The two key distinctions of the approach to integrated business intelligence incorporated in PMT are: 1) standardized business documents as a key user interface, and 2) a “schema-less” XML database enables integration. These key features distinguish PMT from an entire category of existing project and program management tools such as (Tool) that are commercially available.

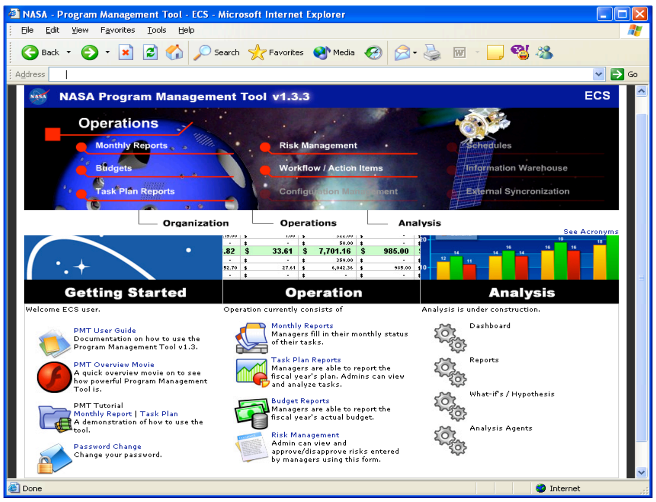

Figure 1 – PMT Portal

The design philosophy of PMT has been to develop a powerful program management information system while providing a simple and intuitive user interaction through standardized business documents in all stages of the program management lifecycle. PMT supports all essential program management activities and corresponding documents such as creation and monitoring of annual task plans; monthly reporting of technical, schedule, management, and budget status; tracking budget phasing plans; analyzing program risks and mitigation strategies; reporting and evaluating project life cycle costs; accessing convenient aggregated views; and automatically creating Quadcharts and other reports. It is a comprehensive, web-enabled tool which provides an intuitive and enhanced web interface for all user activities from setting up the basic program configuration, to creating reports and charts. Alternatively, data input can be easily done off-line by downloading annual task plans, monthly reports and other documents to a local desktop. They can be edited with conventional spreadsheet software and uploaded to PMT by the push of a button. Figure 2 provides an illustration of a typical input document:

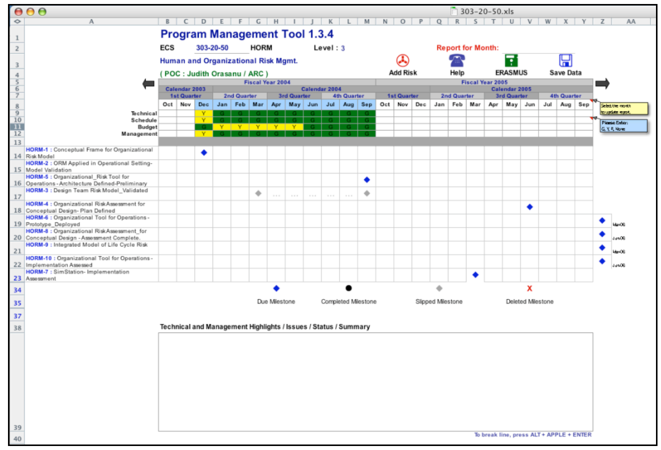

Figure 2 – Spreadsheet as PMT Input

At NASA input documents such as Task Plans and Monthly reports are typically in formats such as Microsoft® Excel, Microsoft® Word, Microsoft® Powerpoint® and Adobe® Acrobat® since they can be easily distributed by email. PMT users just take the spreadsheets, presentations, and reports that they use in their day-to-day activities to input data into the PMT system. This input process is extremely simple, typically requiring users to upload information through a web server, or simply drag and drop documents into (Web DAV[3]) folders on the desktop. The input data is automatically converted into XML and stored in a high-throughput information management system. (Discussed in detail in the Technical Details section).

PMT can automatically generate aggregated documents from several input documents from multiple programs, very quickly. For instance PMT has been used to automatically generate NASA IBPDs (Integrated Budget Performance Documents) spreadsheets using rollup approaches, thus saving significant time and eliminating budget errors. The details and benefits are discussed further in the conclusions section. Other examples of the aggregated documents such are integrated budget reports or summary Quad-Charts that can be automatically created by PMT.

PMT is also interfaced and interoperable with existing NASA information systems. For instance it is connected to the ERASMUS[4] reporting system and to the NASA Technology Inventory[5], thereby significantly reducing cost and time for entering the same data multiple times into different systems.

3———————————————

[3] Discussed shortly

[4] http://www.hq.nasa.gov/erasmus/splash_nasa.htm : A NASA project performance dashboard

[5] http://inventory.gsfc.nasa.gov/ : Database of NASA ongoing technology activities

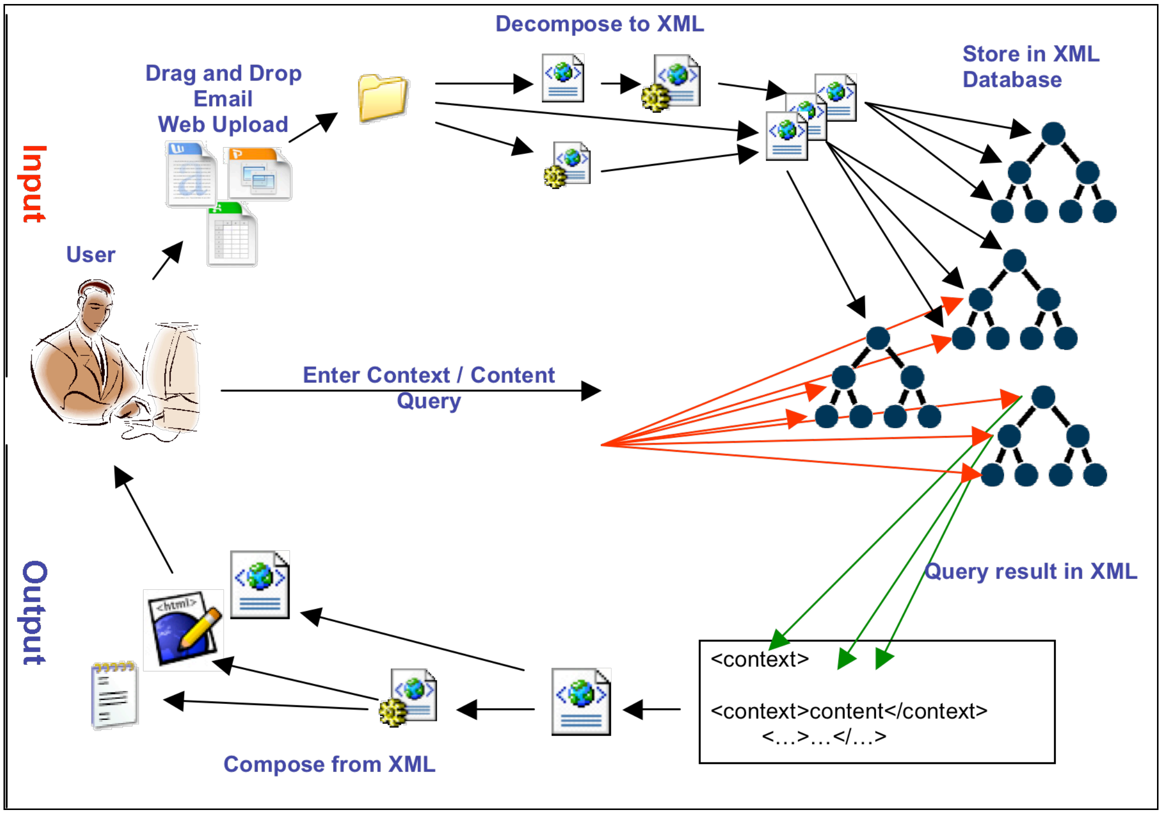

Figure 3 – PMT Document Workflow

In essence, PMT acts like the nervous system of a complex living organism—it rapidly transports vital information from its operating parts to decision-making authorities and back, allowing a program to move ahead in a coherent and efficient manner and to master changes in the environment fast and proactively.

A schematic illustration of the information workflow is provided in Figure 3 above. While information storage and other details are discussed in the following section, we must stress that this approach manages information using open and interoperable standards (i.e., XML) but without enforcing day to day users to mark-up their data in any particular format. We begin with enterprise information in business documents which is converted automatically to XML for storage, management, and integration, and which is then composed and formatted for output to business documents and applications as needed for end applications.

4. PMT ARCHITECTURE

A high level architectural description of PMT is illustrated in Figure 4 on the next page. The architecture is based on two primary levels: 1) client and 2) Netmark-XDB[6] service; the figure also shows on a more detailed level internal components and communication between components.

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[6] The term Netmark and XDB are used interchangeably in this paper.

At the heart of PMT is a high-throughput information integration and management system, also developed at NASA, called Netmark-XDB [1]. The key design considerations held in the Netmark system design are outlined below:

- Enabling meaningful government-to-government information sharing using international standards, in order to improve mission safety and success
- Enabling effective information management systems that utilize indigenous user interfaces (e.g., spreadsheets as user interfaces), in order to improve system usability
- Enabling rapid development of customized system applications with an enabling platform, in order to reduce time from system concept to system deployment
- Eliminating the need for database analysts using a ‘schema-less’ design, in order to reduce system maintenance costs

Netmark supports the XML standard for metadata and information interchange thus making it an open system that is interoperable with a wide variety of other information systems and tools.

Netmark is essentially a data management system for "semi-structured" data i.e., data in the above enumerated kinds of business documents (such as reports in Word or PDF, presentations in formats such Powerpoint, Excel spreadsheets etc) which does not have a formal "schema", but where there is indeed some structure in the document implicit from the format and layout. Data loaded into Netmark (done by simple drag and drop) is converted into XML and stored in the data store. The data store is an XML-over-relational data management system. Data can be retrieved very conveniently from Netmark using simple Web-based interfaces that require simple keyword-based input. Netmark also provides powerful data aggregation and composition capabilities, for the details of which we gain refer the reader to.

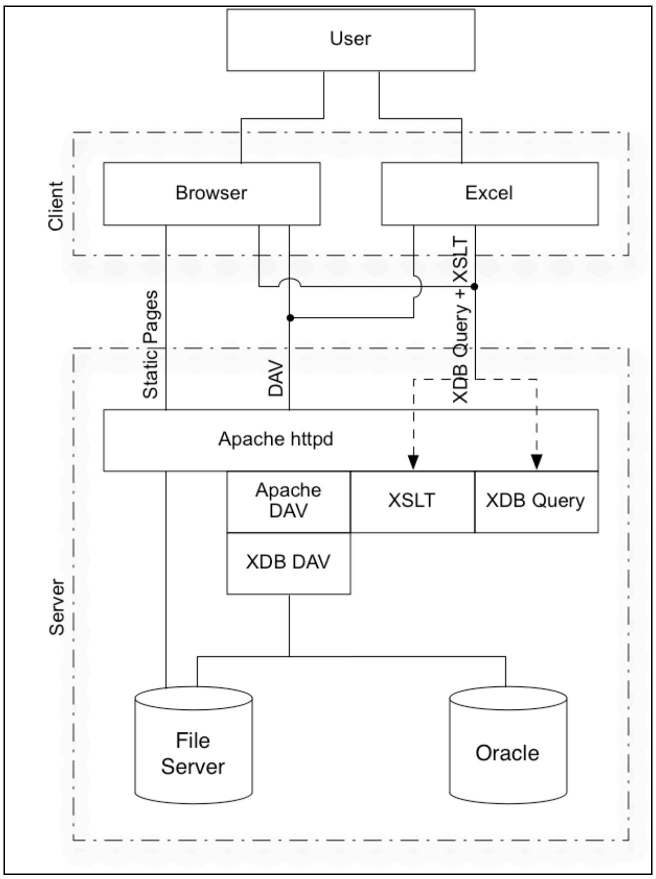

Figure 4 – PMT Software Architecture

Clients communicate with the XDB service exclusively over the standards-compliant HTTP[7] and WebDAV[8] protocol extensions. The protocol-specific headers, client authentication, and feature negotiations are managed by the HTTP server framework—currently Apache's HTTPD[9]. Information storage, retrieval, and recomposition modules connect to the Apache server and provide their services through handler API's as defined in the Apache framework.

The XDB DAV module handles WebDAV requests for document storage and retrieval—including decomposition via a pipeline system and storage of decomposed documents in the XDB data store. Information is protected with a full-featured access control mechanism to ensure data security. The XDB Query module provides XDB datastore querying capabilities including content and context querying, information recomposition, server-side transformation (using the Xalan[10] XSLT[11] processor), and information access control enforcement.

5. CONCLUSIONS

PMT has been in use at NASA for about four years, initially for all projects in a $40M technology research and development program, subsequently for all projects in a $500M+ research and development program, and has begun to be used by some projects and is under consideration for use by all projects in a multi-billion dollar technology research and development program. PMT has been cited as a key source of the successful passing of the $40M program's Non-Advocate Review (NAR) by the U.S. Office of Management and Budget, and as a factor in the passing of the $500M+ program's NAR. The adoption and positive feedback from program manager's and non-advocate reviewers provides qualitative measure of positive results from using PMT.

Quantitative results can be measured in terms of the integrity of the business documents used for management of these technology programs. As one measure of the integrity of information, program and project documents utilized before and after the implementation of PMT on the $500M+ program were compared, with emphasis on discrepancies that occurred between centrally administered registries and local project documents around milestones and deliverables. Milestones and deliverables represent one of the most important aspects of the agreement between program and project managers. Differences in program and project manager's understandings of the agreed upon milestones can have significant impact on the project's and program's success. Table 1 shows that under 60% of all level three project milestones had complete integrity between the project's documents and the program's documents. Table 2 shows the breakdown in information integrity for each of seven major projects, with levels of information integrity varying from under 24% to 100%.

With the use of PMT the integrity of business documents became 100% throughout, output documents were automatically created from input documents without any manual cutting & pasting of information.

[7] HyperText Transport Protocol – http://www.w3.org/Protocols/

[8] Web Distributed Authoring and Versioning Protocol – http://www.webdav.org/specs/

[9] Apache HTTPD Version 2 – http://httpd.apache.org/

[10] Apache Xalan C++ XSLT Engine – http://xml.apache.org/xalan-c/index.html

[11] The Extensible Stylesheet Language – http://www.w3.org/Style/XSL/

Table 1 – Differences in milestone data for a major program prior to the use of PMT

	Different MS #		Different Date		Different MS Description		Any Difference	
	Count	%	Count	%	Count	%	Count	%
match	267	85.3%	259	82.7%	232	74.1%	185	59.1%
mismatch	43	13.7%	51	16.3%	74	23.6%	121	38.7%
missing	7	1.0%	7	1.0%	7	2.2%	7	2.2%
Total	313	100.0%	313	100.0%	313	100.0%	313	100.0%

Table 2 – Differences in milestone data for specific projects in a major program prior to the use of PMT

		Different MS #		Different Date		Different MS Description		Any Difference?	
		Count	%	Count	%	Count	%	Count	%
Project 1	match	57	76.0%	66	88.0%	54	72.0%	37	49.3%
	mismatch	18	24.0%	9	12.0%	21	28.0%	38	50.7%
	missing								
	Total	75	100.0%	75	100.0%	75	100.0%	75	100.0%
Project 2	match	38	100.0%	38	100.0%	38	100.0%	38	100.0%
	mismatch								
	missing								
	Total	38	100.0%	38	100.0%	38	100.0%	38	100.0%
Project 3	match	28	90.3%	29	93.5%	27	87.1%	26	83.9%
	mismatch	2	6.5%	1	3.2%	3	9.7%	4	12.9%
	missing	1	3.2%	1	3.2%	1	3.2%	1	3.2%
	Total	31	100.0%	31	100.0%	31	100.0%	31	100.0%
Project 4	match	46	90.2%	45	88.2%	35	68.6%	29	56.9%
	mismatch	5	9.8%	6	11.8%	16	31.4%	22	43.1%
	missing								
	Total	51	100.0%	51	100.0%	51	100.0%	51	100.0%
Project 5	match	21	100.0%	20	95.2%	18	85.7%	17	81.0%
	mismatch			1	4.8%	3	14.3%	4	19.0%
	missing								
	Total	21	100.0%	21	100.0%	21	100.0%	21	100.0%
Project 6	match	15	42.9%	9	42.9%	9	42.9%	5	23.8%
	mismatch	4	47.6%	10	47.6%	10	47.6%	14	66.7%
	missing	2	9.5%	2	9.5%	2	9.5%	2	9.5%
	Total	21	100.0%	21	100.0%	21	100.0%	21	100.0%
Project 7	match	62	81.6%	52	68.4%	51	67.1%	33	43.4%
	mismatch	10	13.2%	20	26.3%	21	27.6%	39	51.3%
	missing	4	5.3%	4	5.3%	4	5.3%	4	5.3%
	Total	76	100.0%	76	100.0%	76	100.0%	76	100.0%

REFERENCES

[1] David Maluf and Peter Tran, "NETMARK: A Schema-less Extension for Relational Databases for Managing Semi-Structured Data Dynamically," Proceedings of the 14th International Symposium on Methodologies for Intelligent Systems, October 28-31, 2003, 231-241

BIOGRAPHY

David Bell *is Director and Senior Scientist at the Research Institute for Advanced Computer Science, located at the NASA Ames Research Center. Prior to working at NASA, David worked for ten years at the Xerox Palo Alto Research Center, and previously held an appointment at MIT where he led a research program in the Center for Innovation in Product Development. David is co-inventor of multiple patent and patent-pending information system technologies, including XML query technologies related to NETMARK and the NASA Program Management Tool, extensible blog technology called Sparrow Web, and distributed knowledge management software called Eureka. David received his Ph.D. from Cornell University with a dissertation on the dynamics of product development processes.*

Yuri Gawdiak *is a program integration manager for NASA's Aeronautics Research Mission Directorate and has been working advanced information systems and strategic planning for twenty years. He has worked in industry, academia, and government covering space, aeronautics, human factors, and engineering research. At NASA he has worked at Johnson Space Flight Center on the Space Station program including principal investigator for the Wireless Network Experiment on STS-76/Mir-21. He earned his BS in information systems with a concentration in ergonomics at Carnegie Mellon University. For his work in Personal Satellite Assistant as well as other programs and project Mr. Gawdiak has been awarded both the NASA Outstanding Leadership and Exceptional Achievement medals.*

David A. Maluf *leads the NASA Advanced Exploration Network laboratory (AEN), a laboratory consisting of 20+ staff with an average of 12 projects/year. He has over 70 technical publications in journals and conference proceedings, over hundreds of presentations at international conferences and is an inventor of numerous patents. He has taught courses on system engineering and databases, and has written two books. He received his PhD from McGill University and conducted post-doctoral research in information integration at Stanford University.*

Peter Putz *is a management scientist with the Research Institute for Advanced Computer Science (RIACS) at the NASA Ames Research Center. Previously he was a member of research staff with the Xerox Palo Alto Research Center (which is now PARC Inc.) where he was doing research on learning and knowledge sharing strategies together with an interdisciplinary group of social scientists in the Knowledge, Interaction and Practice Area. Peter received his Ph.D. for the Johannes Kepler University Linz, Austria. There he was an assistant professor with the Department of Business Information Systems and the Department of Management for more then ten years.*

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